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(71) Applicant(s)
Sony Corporation
(Incorporated in Japan)
7-35 Kitashinagawa 6-chome, Shinagawa-ku, Tokyo, Japan

(72) Inventor(s)
Hideaki Hanaoka
Fumiaki Hisamatsu
Masataka Yamashita
Masahiro Kobayashi

(74) Agent and/or Address for Service
D Young & Co
21 New Fetter Lane, LONDON, EC4A 1DA, United Kingdom

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(54) Abstract Title
Anti-reflection film and display device

(57) An anti-reflection film enabling adjustment of light transmittance in a wide range and a display device having a desirable display quality is achieved by forming an anti-reflection film on the surface of a panel base for displaying an image. The anti-reflection film includes first and second optical absorption films, each of which is composed of at least one kind selected from a group consisting of a metal film, a metal nitride film and a metal oxide film, and a dielectric film having a refractive index ranging from about 1.4 to about 1.9, which is formed between the first and second optical absorption films. For example, the following three films are sequentially formed on a panel glass for a Braun tube: a first optical absorption film of TiN having a thickness of 10 nm; a dielectric film of Al_2O_3 having a thickness of 82 nm; and a second optical absorption film of TiN having a thickness of 12 nm, to thus form an anti-reflection film.

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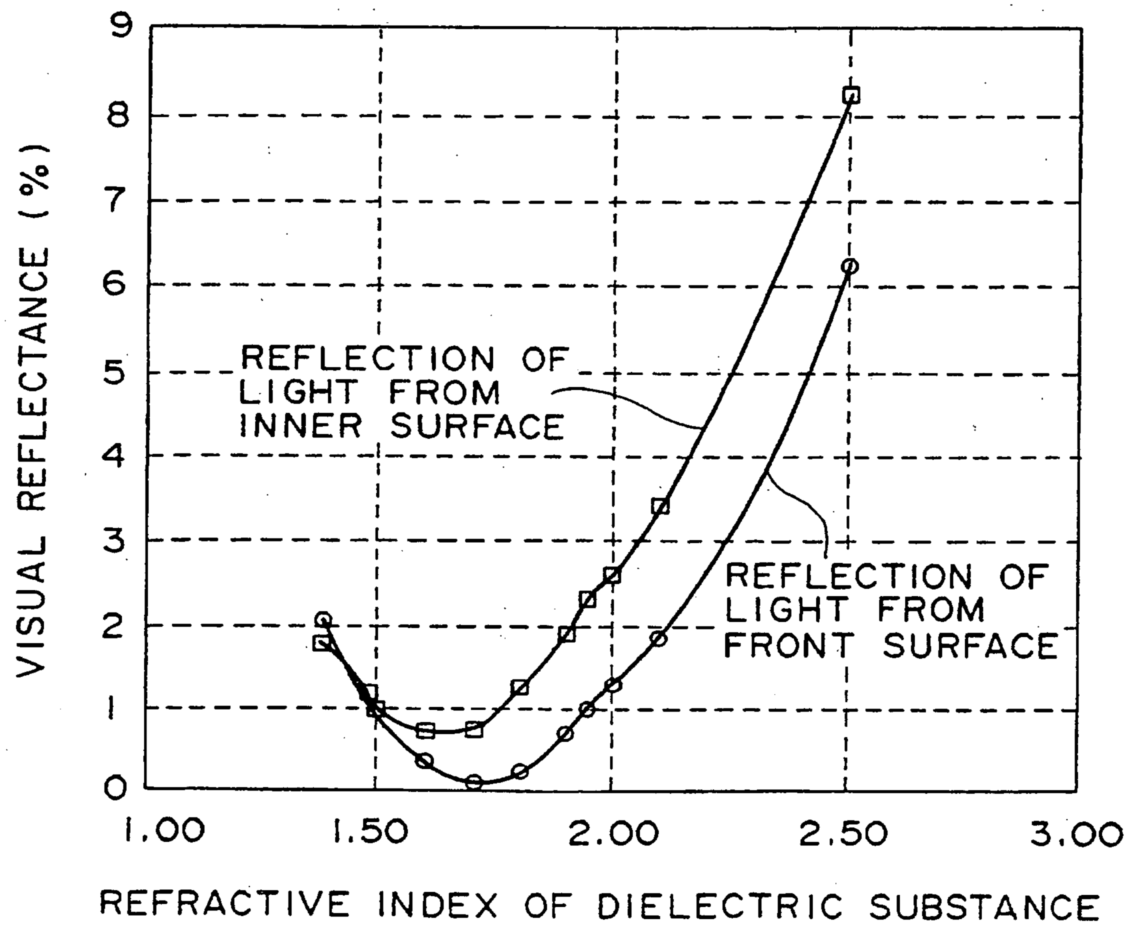
9
8
7
6
5
4
3
2
1
0
VISUAL REFLECTANCE (%)
REFLECTION OF LIGHT FROM INNER SURFACE
REFLECTION OF LIGHT FROM FRONT SURFACE
1.00
1.50
2.00
2.50
3.00
REFRACTIVE INDEX OF DIELECTRIC SUBSTANCE

2344600

ANTI-REFLECTION FILM AND DISPLAY DEVICE

The present invention relates to an anti-reflection film and a display device, and more particularly to an anti-reflection film for preventing reflection of external light and a display device in which the anti-reflection film is formed on the surface of a panel base for displaying an image.

When a person takes a look at an object through a transparent material such as spectacle lenses, he perceives a phenomenon called ghost or flare which is a reflected image clearly appearing if the intensity of the reflected light becomes strong.

On the other hand, a general window glass or a shopwindow glass causes an in-glass imaging phenomenon which happens by mirror-reflection of environmental light such as sunlight or illuminating light from the window glass. Such an in-glass imaging phenomenon may degrade the transparency of the window glass. To cope with this inconvenience, an attempt has been made to form, on a base, an anti-reflection film made from a material different in refractive index from a material of the base by a vacuum vapor-deposition process or the like. In this case, as is well-known, to maximize the reflection preventive effect, it is important to suitably select the thickness of a coating formed on the base. For example, it is known that for a single-layer coating, the minimum reflectance, that is, the maximum transmittance of the coating can

obtained by selecting an optical film thickness of a coating material, having a refractive index lower than that of a material of the base, at 1/4 (or its odd multiples) of the wavelength of the objective light. It should be noted that the optical film thickness of the coating material is given by a product of the refractive index of the coating material and the film thickness of the coating material. The anti-reflection film can be configured by stacking a plurality of layers on the base. With respect to such an anti-reflection film having a multi-layer structure, various techniques relating to selection of the thickness of each layer have been proposed, for example, in "Optical Technique Contact", Vol. 9, No. 8, page 17, 1971. The coating constituting the above anti-reflection film is mainly made from an inorganic oxide or an inorganic halide, and it has generally a low reflectance in combination with a high transmittance in a visual light region.

Even in a display device such as a Braun tube or a liquid crystal display device, there may occur an inconvenience that an image becomes unclear due to reflection of external light or illuminating light in a screen, and in many cases, an anti-reflection film for preventing such front surface reflection is formed on the surface of a panel base for displaying an image. On the other hand, in the display device, depending on its structure or application, the light transmittance of the panel base is required to be adjusted in a range of 20 to 92% for improving the contrast. For example, in the panel base such as a panel glass for a Braun tube or an acrylic resin made front plate of a transmission

type projector (rear projector), the light transmittance is adjusted by changing the light transmittance of the panel base itself.

The panel base for displaying an image, however, plays a role of keeping the mechanical strength of the display device. That is to say, if the display device is enlarged, the panel base must be made thick. In order to change the light transmittance of the panel base thus made thick, it has been required to prepare various kinds of panel bases varied in transmittance by changing the degree of a dye or the concentration of a pigment.

Further, for a panel glass as the panel base for a Braun tube, the central portion is thin and the end portion is thick for ensuring a sufficient mechanical strength. As a result, in the case of adjusting the light transmittance of the panel glass by changing the light transmittance of the panel glass itself, there has arisen a problem that the light transmittance at the central portion is different from that at the end portion. In particular, for the recent Braun tube in which a display screen for displaying an image is taken as a substantially flat plane, since the central portion becomes thinner and the end portion becomes thicker to increase the mechanical strength, the difference in light transmittance between the central portion and the end portion becomes larger.

One type of heat ray cutoff film components utilizing optical thin films is configured such that an optical absorption film is formed of a metal thin film for adjusting a light transmittance. Specific examples of materials for forming the optical absorption

films may include Au, Pt, Ni-Cr, Al, In_2O_3-SnO_2, CuI and CuS. Such a heat ray cutoff film has a visual light transmittance which is preferably in a range of 60 to 90%. Specific examples using such an optical absorption film as an anti-reflection film may include a dark mirror, selective absorption mirror or enhanced absorption mirror. As an anti-reflection film in a visual light region, a configuration called a "dark mirror" can be utilized. For example, a double layer dark mirror in which an optical absorption film is combined with a dielectric film is described in "Optical Thin Film User Handbook", page 160 (published by Nikkan Kogyou Shinbunsha). Japanese Patent Laid-open No. Hei 9-156964 discloses a technique in which a metal nitride film made from TiN, ZrN or HfN is used as an optical absorption film, to thereby obtain a low reflectance in a wide visual light region. U.S. Patent No. 5,091,244 discloses an anti-reflection film having a structure of four to six layers, in which a metal or metal nitride film is used as an optical absorption film, to thereby enable adjustment of a light transmittance while keeping a low reflectance in a visual light region.

In the case of making use of the material, which is suitable for forming the above optical absorption film, as part of the anti-reflection film, however, there arises a problem. For example, in the technique disclosed in Japanese Patent Laid-open No. Hei 9-156964, the reflectance of light from the front surface of the panel base is sufficiently low but the reflectance of light from the inner surface of the panel base is as high as 5 to 10%. In the display device, the reflection of light from the inner surface of

the panel base may cause double vision (or a ghost) of a character or an image or make obscure the contour of a character or an image, resulting in the significantly degraded display quality. In the anti-reflection film disclosed in U.S. Patent No. 5,091,244, it teaches the manner of reducing the reflection of light from the front surface while controlling the light transmittance; however, it does not examine reduction in reflection of light from the inner surface of the panel base, which is the important matter of the display device as described above, with a result that the reflectance of light from the inner surface of the panel base is as high as 8 to 20%.

If the light transmittance of the panel base for a Braun tube is as low as 35 to 60%, the reflection of light from the inner surface of the panel base does not cause problem so much because the reflected light from the inner surface is decayed by allowing the reflected light to pass through the panel base three times. On the contrary, if the light transmittance of the panel base for a Braun tube is 60% or more, for example, in the case of using the panel base exhibiting the grade "Clear" (transmittance: 75% or more) or the grade "Gray" (transmittance: 60-75%) specified under EIAJ ED-2138, the reflection of light from the inner surface of the panel base causes a non-negligible problem.

An aim of the present invention is to provide an anti-reflection film enabling adjustment of a light transmittance in a wide range and to provide a display device having a desirable display quality.

Accordingly, the present invention provides an anti-reflection film which has a multi-layer structure in which a plurality of thin films are stacked on a base, characterized in that the thin films include: a first optical absorption film composed of at least one kind selected from a group consisting of a metal film, a metal nitride film and a metal oxide film; a second optical absorption film composed of at least one kind selected from a group consisting of a metal film, a metal nitride film and a metal oxide film; and a dielectric film having a refractive index ranging from about 1.4 to about 1.9, the dielectric film being disposed between the first optical absorption film and the second optical absorption film.

The present invention also provides a display device in which an anti-reflection film is formed on the surface of a panel base for displaying an image, characterized in that the anti-reflection film includes: a first optical absorption film composed of at least one kind selected from a group consisting of a metal film, a metal nitride film and a metal oxide film; a second optical absorption film composed of at least one kind selected from a group consisting of a metal film, a metal nitride film and a metal oxide film; and a dielectric film having a refractive index ranging from about 1.4 to about 1.9, the dielectric film being disposed between the first optical absorption film and the second optical absorption film. In this display device, the panel base preferably has a light transmittance in a range of 60% or more.

Other aims and advantages of the invention will become apparent upon reading the following detailed description and appended claims, and upon reference to the accompanying drawings.

Preferred embodiments of the present invention will now be described hereinbelow by way of example only with reference to the accompanying drawing, in which:

Fig. 1 is a graph showing changes in reflection of light from the front surface and reflection of light from the inner surface depending on a change in refractive index of a dielectric film formed between two optical absorption films of an anti-reflection film of the present invention.

It should be understood that the drawings are not necessarily to scale and that the embodiments are sometimes illustrated by graphic symbols, phantom lines, diagrammatic representations and fragmentary views. In certain instances, details which are not necessary for an understanding of the present invention or which render other details difficult to perceive may have been omitted. It should be understood, of course, that the invention is not necessarily limited to the particular embodiments illustrated herein.

The panel base for a display device can be made from a glass material or a synthetic resin material. Specific examples of the glass materials may include soda glass, lead glass, hard glass, quartz glass, and liquid crystal glass. For a Braun tube, silicate glass containing strontium or barium is preferably used, and for a liquid crystal display device, alkali-less glass is preferably used.

As the synthetic resin material for forming the panel base, any kind of organic high polymer materials may be used. However, from the viewpoint of optical characteristics such as transparency, refractive index and dispersion and other characteristics such as impact resistance, heat resistance and durability, there may be preferably used a (meth)acrylic based resin such as polymethylmethacrylate, or a copolymer of methylmethacrylate and a vinyl monomer such as alkyl(meth)acrylate or styrene; a polycarbonate based resin such as polycarbonate, or diethylene glycol bisallyl carbonate (CR-39); a thermosetting (meth)acrylic based resin such as a single polymer or copolymer of (brominated) bisphenol A-type di(meth)acrylate or a single polymer or copolymer of urethane-modified (brominated) bisphenol A-mono (meth)acrylate; polyester, particularly, polyethyleneterephthalate, polyethylenenaphthalate or unsaturated polyester; acrylonitrile-styrene copolymer; polyvinyl chloride; polyurethane; or epoxy resin. Further, an aramid based resin can be used from the viewpoint of heat resistance. A film-like base can be produced by drawing the above-described synthetic resin material, or diluting the above-described synthetic resin material with a solvent, applying the diluted material in a film-like shape, and drying it. The thickness of the film-like base is generally in a range of 25 to 500 μm.

If the panel base for the display device is made from a synthetic resin material, the surface of the panel base may be coated with a coating material such as hard coat disclosed in Japanese Patent Publication Nos. Sho 50-28092, Sho 50-28446, Sho

51-24368, Japanese Patent Laid-open No. Sho 52-112698, and Japanese Patent Publication No. Sho 57-2735. Also, for the panel base made from a synthetic resin material, various characteristics thereof such as adhesion, hardness, chemical resistance, durability and dye-affinity can be improved by providing an inorganic covering material as an underlying layer of an anti-reflection film. The thickness of the hard coat is generally in a range of about 3 to 20 μm. Further, the panel base for the display device may be colored by a pigment such as carbon black or a dye. In this case, as disclosed in Japanese Patent Publication No. Hei 7-36044, the panel base thus colored can serve as a selective absorption filter which selectively absorbs light having a specific wavelength.

The anti-reflection film containing an optical absorption film can be formed by a PVD (Physical Vapor Deposition) process represented by a vacuum vapor deposition process, an ion plating process, or a sputtering process. Specific examples of materials suitable for forming an optical absorption film by the PVD process may include metals such as Au, Pt, Pd, Fe, Fe-Ni, Ni-Cr, Ni-V, Al, Ag, Cr, Fe-Cr, Cu, Ti, Zr, and Hf, and nitrides and oxides thereof. Further, specific examples of materials for forming a dielectric film may include inorganic oxides and inorganic nitrides such as SiO_2, SiO, Si_3N_4, Al_2O_3, ZrO_2, TiO_2, Ta_2O_5, $TaHf_2$, TiO, Ti_2O_3, HfO_2, ZnO, In_2O_3, In_2O_3/SnO_2, Y_2O_3, Yb_2O_3, Sb_2O_3, MgO, and CeO_2.

An oxidation barrier layer for preventing oxidation of an optical absorption film may be inserted in the anti-reflection film, as disclosed in Japanese Patent Laid-open Nos. Sho 59-165001 and Hei 9-156964. Specific examples of materials for forming the

above oxidation barrier layer may include various metals and metal nitrides such as Si_3N_4 or AlN.

The oxidation barrier layer is unnecessary from the optical viewpoint, and therefore, the thickness of the oxidation barrier layer is preferably in a range of 20 μm or less for preventing deterioration of the reflection preventive characteristic. Further, if the panel base is made from a synthetic resin material, as disclosed in U.S. Patent No. 2,628,927 and Japanese Patent Publication No. Hei 3-81121, a film of a metal oxide such as SiO_2 or a metal sulfide may be extremely thinly formed as a first layer (adhesive layer) of the anti-reflection film for improving the adhesion between the panel base and the anti-reflection film.

According to the above-described means, it is possible to provide an anti-reflection film having a desirable reflection preventive characteristic with a minimum number of layers. In a display device in which such an anti-reflection film is formed on the surface of a panel base for displaying an image, it is possible to adjust the light transmittance in a wide range without the necessity of preparing various panel bases varied in light transmittance as conventional. Also, in this display device, since a uniform light transmittance can be obtained over the entire surface of the panel base for displaying an image irrespective of the mechanical strength of the display device, it is possible to ensure a good display quality without occurrence of ghost or flare due to reflection of light from the inner surface of the panel base.

The present invention is applicable to an anti-reflection film having a multi-layer structure in which a plurality of thin films are formed on a base, and to a display device in which the above anti-reflection film is formed on the surface of a panel base for displaying an image. Hereinafter, there will be described one example using an anti-reflection film formed on the surface of a panel base represented by a panel glass ("Clear" glass specified under EIAJ H-8601) for a Braun tube. In addition, the thickness of a central portion of a display plane of the panel glass is 12 mm. It should be noted that the present invention is of course not limited thereto.

Inventive Example 1

In this example, the following four films were sequentially formed on the panel glass for a Braun tube: a first optical absorption film of TiN having a thickness of 10 nm, a dielectric film of Al_2O_3 (refractive index: about 1.7) having a thickness of 82 nm; a second optical absorption film of TiN having a thickness of 12 nm; and a dielectric film of SiO_2 having a thickness of 90 nm, to thus obtain a four-layer anti-reflection film.

Comparative Example 1

In this comparative example, the following two films were formed on the panel glass for a Braun tube: a first optical absorption film of TiN having a thickness of 10 nm); and a dielectric film of SiO_2 (refractive index: about 1.4) having a thickness of 87 nm, to thus obtain a two-layer anti-reflection film. In this comparative example, the second optical absorption film is not formed.

Comparative Example 2

In this comparative example, the following four films were sequentially stacked on the panel glass for a Braun tube: a first optical absorption film of TiN having a thickness of 19.9 nm); a dielectric film of TiO_2 (refractive index: about 2.6) having a thickness of 30 nm); a second optical absorption film of TiN having a thickness of 6.7 nm; and a dielectric film of SiO_2 having a thickness of 82.2 nm, to thus obtain an anti-reflection film. In this comparative example, the refractive index of the dielectric film formed between the first and second optical absorption films is more than 1.9.

The results of simulating the anti-reflection films in Inventive Example 1 and Comparative Examples 1 and 2 using a computer are shown in Table 1. As the complex refractive indexes of the film materials used for the simulation, values obtained on the basis of a relationship of the complex refractive index = (n – ik) and shown in Table 2 were used. It should be noted that for a dielectric substance, k becomes zero.

Table 1

	Reflectance of light from front surface (Visual reflectance)	Reflectance of light from inner surface (Visual reflectance)	Transmittance (Wavelength: 546 nm)
Inventive Example 1	0.1 %	0.8 %	53 %
Comparative Example 1	0.1 %	6.6 %	75 %
Comparative Example 2	0.1 %	16.8 %	48 %

Table 2

Film material	Complex refractive index	Wavelength		
		450 nm	550 nm	650 nm
TiN	Refractive index (n)	2.00	1.75	1.70
TiN	Extinction coefficient (k)	0.95	1.20	1.67
Al_2O_3	Refractive index (n)	1.67	1.67	1.67
SiO_2	Refractive index (n)	1.46	1.46	1.45

As is apparent from Table 1, for the anti-reflection film obtained in Inventive Example 1, the visual reflectance of light reflected from the front surface is 0.1%; the visual reflectance of light reflected from the inner surface is 0.8%; and the transmittance of light having a wavelength of 546 nm is 53%. These results satisfy requirements of the display device. On the contrary, for the anti-reflection films obtained in Comparative Examples 1 and 2, the visual reflectance of light reflected from the front surface is as low as 0.1%; however, the visual reflectance of light reflected from the inner surface is as high as 6.6% for Comparative Example 1 and as high as 16.8% for Comparative Example 2. These results do not satisfy the requirements of the display device.

Fig. 1 is a graph showing a relationship between the luminous reflectance and the refractive index of a dielectric substance forming a dielectric film of an anti-reflection film. To be more specific, the following four layers were sequentially formed on a transparent glass as the panel base: an optical absorption film of TiN having a thickness of 10 nm, a dielectric film (quarter-wave film); an optical absorption film of TiN having a thickness of 12 nm; and a dielectric film of SiO_2 having a thickness of 90 nm, to

form an anti-reflection film. For such an anti-reflection film, the visual reflectance of light reflected from each of the front surface and inner surface was calculated with the refractive index of the dielectric substance of the dielectric film taken as a parameter.

The reflectance of light reflected from each of the front surface and inner surface of a panel base made from a glass material or a synthetic resin material is in a range of about 4 to 6%. One criterion for determining the reflection preventive effect required for a display device is specified under Europe Standard TUV. To satisfy such a standard, the visual reflectance must be suppressed at a value of 2% or less (see Television Society's Technical Report, Vol. 19, No. 2, 1995). Even in the above-described simulation results, in order for both the reflectance of light from the front surface and the reflectance of light from the inner surface to be simultaneously in a range of 2% or less, the refractive index of the dielectric film is required to be in a range of 1.4 to 1.9, preferably, in a range of 1.5 to 1.8.

The present invention can provide an anti-reflection film having a desirable reflection preventive function with a minimum number of layers. The display device in which the anti-reflection film is formed on the surface of a panel base for displaying an image has the following effects:

(1) The light transmittance can be adjusted in a wide range without the necessity of preparing various kinds of panel bases varied in light transmittance as conventional.

(2) A desirable display quality without occurrence of ghost or flare due to reflection of light from the inner surface of the panel base can be ensured.

(3) A uniform light transmittance can be obtained over the entire surface of the panel base for displaying an image irrespective of the mechanical strength of the display device.

While preferred embodiments of the present invention have been described using specific terms, such description is for illustrative purposes only, and it is to be understood that changes and variations may be made without departing from the scope of the invention as defined by the appended claims.

CLAIMS

1. An anti-reflection film having a multi-layer structure in which a plurality of thin films are stacked on a base, the anti-reflection film comprising:

a first optical absorption film selected from a group consisting of a metal, a metal nitride and a metal oxide;

a second optical absorption film selected from a group consisting of a metal, a metal nitride and a metal oxide; and

a dielectric film having a refractive index ranging from about 1.4 to about 1.9, said dielectric film being disposed between said first optical absorption film and said second optical absorption film.

2. The anti-reflection film of claim 1 wherein the metal of the first optical absorption film comprises a metal, a metal nitride or a metal oxide selected from the group consisting of Au, Pt, Pd, Fe, Fe-Ni, Ni-Cr, Ni-V, Al, Ag, Cr, Fe-Cr, Cu, Ti, Zr, and Hf, and nitrides and oxides thereof.

3. The anti-reflection film of claim 1 wherein the metal of the second optical absorption film comprises a metal, a metal nitride or a metal oxide selected from the group consisting of Au, Pt, Pd, Fe, Fe-Ni, Ni-Cr, Ni-V, Al, Ag, Cr, Fe-Cr, Cu, Ti, Zr, and Hf, and nitrides and oxides thereof.

4. The anti-reflection film of claim 1 wherein the dielectric film comprises a material selected from the group

consisting of SiO_2, SiO, Si_3N_4, Al_2O_3, ZrO_2, TiO_2, Ta_2O_5, $TaHf_2$, TiO, Ti_2O_3, HfO_2, ZnO, In_2O_3, In_2O_3/SnO_2, Y_2O_3, Yb_2O_3, Sb_2O_3, MgO, and CeO_2.

5. A display device in which an anti-reflection film is formed on the surface of a panel base for displaying an image, the anti-reflection film comprising:

a first optical absorption film selected from a group consisting of a metal, a metal nitride and a metal oxide;

a second optical absorption film selected from a group consisting of a metal, a metal nitride and a metal oxide; and

a dielectric film having a refractive index ranging from about 1.4 to about 1.9, said dielectric film being disposed between said first optical absorption film and said second optical absorption film.

6. The display device of claim 5 wherein said panel base has a light transmittance in a range of 60% or more.

7. The display device of claim 5 wherein the metal of the first optical absorption film comprises a metal, a metal nitride or a metal oxide selected from the group consisting of Au, Pt, Pd, Fe, Fe-Ni, Ni-Cr, Ni-V, Al, Ag, Cr, Fe-Cr, Cu, Ti, Zr, and Hf, and nitrides and oxides thereof.

8. The display device of claim 5 wherein the metal of the second optical absorption film comprises a metal, a metal nitride or a metal oxide selected from the group consisting of Au,

Pt, Pd, Fe, Fe-Ni, Ni-Cr, Ni-V, Al, Ag, Cr, Fe-Cr, Cu, Ti, Zr, and Hf, and nitrides and oxides thereof.

9. The display device of claim 5 wherein the dielectric film comprises a material selected from the group consisting of SiO_2, SiO, Si_3N_4, Al_2O_3, ZrO_2, TiO_2, Ta_2O_5, $TaHf_2$, TiO, Ti_2O_3, HfO_2, ZnO, In_2O_3, In_2O_3/SnO_2, Y_2O_3, Yb_2O_3, Sb_2O_3, MgO, and CeO_2.

10. An anti-reflection film substantially as hereinbefore described with reference to Figure 1 and/or Inventive Example 1.

11. A display device substantially as hereinbefore described with reference to Figure 1 and/or Inventive Example 1.